

A VISITING SCIENTIST'S OBSERVATIONS AND RECOMMENDATIONS CONCERNING STRIP-MINE RECLAMATION IN OHIO¹

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In my whole life, I have hardly received a more welcome message than Dr. Diller's letter asking me to come over to this country to observe the various kinds of strip-mine reclamation. During the past ten years, I had studied the publications on this subject over and over again, because reclamation of industrial wasteland has become for me a major concern.

Sometimes I ask myself, whence comes this deep interest in reclamation, that has led me from one country into another, from forestry to soil science, and then to agronomy and mining engineering? The source might be the general care of German foresters for their stands, or the first impressions of a totally ruined landscape in the Lausitz mining district. But the roots of this feeling may lie deeper. In the second chapter of Genesis I found the words: "And the Lord took the man, and put him into the garden of Eden to dress it and to keep it." Or in the revised translation: "To till and keep it." I think this care for nature and the natural resources is given us by the Lord to protect mankind from cutting off its own roots, and thus destroying the foundation of all culture and civilization.

RECLAMATION—A WORLD-WIDE EFFORT

Perhaps I ought to report now about the impressions I have gotten in the United States. But I think it would be better to begin with a report on reclamation in some other countries. Reclamation is a world problem, rather than merely an American or German one.

In 1956 Dr. Seidemann, of Leipzig, and I got an invitation from the Czechoslovakian Academy of Agricultural Science to visit the Czech mining areas. This country was just beginning reclamation. We saw a strip-mining industry in its early stages of development, as the Czechs were discontinuing the old underground mining for brown coal. At the same time they began to look for the best ways of reclamation. Encouraged by German successes, they had started cultivated soil management on a large scale, and felt the urgent need for a reclamation act. The most important result of our visit was the formation of the principles of reclamation in that country. The management of topsoil was one of the most important points covered. But this nation also had its own ideas. It had created so-called *Zweckwirtschaften*, well equipped special farms designed to start the agricultural restoration, amelioration, and afforestation of the spoil banks, and the tilling and harvesting of the areas to be strip-mined later. I was glad to read that reclamation has continued to make good progress there (Stys, 1961).

Two years later I visited Hungary for the same purpose. In that country, development had not advanced so far. The mining industry had not yet recognized that it was economically profitable to reclaim the strip-mined areas. But the Hungarian foresters had started afforestation of industrial wasteland, and Laszlo Szoenyi (in 1956) had made his first investigations on such sites. Some

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years later, also, the Hungarians got a reclamation act, and thus joined the world-wide campaign for soil conservation and protection of nature.

In 1961 I visited Belgium. There were no strip mines, but there were a lot of colliery waste piles in the eastern part of the country (Masson, 1950). There was little systematic planting on these spots and the administration knew that something was not in order. Some years earlier, a national service called the "Green Plan" (*Service du plan vert*) had been established, and this authority looked for ways to revegetate the culm banks.

Just before my trip to the United States in May, 1962, I visited the little-known mining district in Middle Jutland, Denmark. This was an interesting trip. The Danes have no reclamation law; afforestation is a voluntary matter. The government contributes 20 per cent of the cost of afforestation to the mining operator, who undertakes to do it.

But there I found another new idea. The Royal Danish Arboretum in Hors-holm has established a so-called "desert arboretum" in the middle of very poor and unpromising spoil banks. On an area of forty acres, they have planted numerous species of trees and shrubs from round the world. My guide told me that his aim was to find the best plants to revegetate this poor, acid sand under very hard climatic conditions. He hoped to change this desolate "moon" landscape into a fine recreation area. Hybrid aspen (*Populus tremula* \times *P. tremuloides*), Hybrid willows (*Salix repens* \times *S. purpurea*), and European black alder were among the most promising plants (Schlaetzer, 1959).

I could mention a lot of other countries where miners, farmers, foresters, and horticulturists have begun reclamation: for example, England, which was one of the first (Whyte and Sisam, 1949); and the Republic of South Africa, where quite extensive efforts to reclaim the waste material of gold and uranium mines have been made (Chenik, 1960). The Soviet Union too might be mentioned, where the colliery waste piles of the Donbass area have been planted since 1947; and last but not least, far Malaya, where Mitchel (1959) first started reclamation trials in tin-mine spoils in tropical areas. Poland, Hawaii, . . . but I must stop. Let's talk about the United States.

IMPRESSIONS IN AMERICA

My first experience of America was a friendly "Hello" from an unknown American, when my freighter tied alongside the pier in New York City. I got the same friendly welcome in many places during my entire visit. I got so much help, advice, and hospitality that I am glad to have a chance to express my thanks by thinking with you about our problems of reclamation. I said *our* problems and not *your* problems intentionally, because I recognized soon after my arrival, that it is impossible to transplant European methods directly to the United States. One must first see the American problems with American eyes, identify himself with this country. Only then can he use his European experiences in seeking an economic and helpful program for the United States.

Three months is a very short time for studying such a difficult problem as strip-mine reclamation in a foreign country. Hence, I prefer merely to report some impressions. It will be best, I think, if I feel free to say how I see the problems now; perhaps after a second visit I will come to other conclusions. And you, please, take these ideas as an act of goodwill of a foreigner; test them, decide what ones you think useful, and forget what is of no value for your reclamation work. And I will gratefully take much of your experience back to Germany and work for its application in the appropriate places.

MINING

The first impression of a European visitor to an American strip mine is the awareness that mining is a hard job everywhere. I admire the old and young

men who work with this heavy machinery. The coal seams are so thin and the overburden so hard that you must blast and work with specially designed equipment. There are so many problems: sticky clay, hard sandstone, slipping material and erosion, long haul-roads, and last but not least, the competition on the coal market. So I can readily understand, if an operator becomes angry when some people are shouting to him: "You must reclaim, you must reclaim, you must reclaim!" because he has problems enough. And this man is working for the common welfare. Indeed, civilization would not be on its present high level in the United States if there were no mining industry. We cannot live now without electric power for heating, lighting, and refrigerating, to say nothing of radio.

And yet, reclamation is an inseparable part of mining. It can hardly reach a higher level without the improvement of the mining technique itself. Reclamation is a concern of both the mining industry and the public.

At this symposium, we lack a contribution from a qualified mining engineer. I will do my best to fill this gap. People have told me that, so far, the mining-engineering schools have largely ignored strip-mining. I asked in vain for any textbook on the subject. There are many high-quality articles in the mining journals, but no general treatise. "Moving the Earth" by H. L. Nichols (1962) comes nearest this objective, but includes much beside strip mining.

The old generation of strip miners, whom I like so much, have grown up with the development of machinery. They started with small power shovels and draglines, but now Bucyrus has built a stripping shovel of 115 cubic yards, and Marion, draglines of 85 cubic yards. You have seen also the new German bucket wheels and spreaders with a daily capacity of 100,000 to 200,000 cubic yards (Knabe, 1963, Fig. 8B, 8C, 8E). On the other hand, there are now available conveyors, bulldozers, tractor shovels, motor scrapers, and similar types of equipment which have been developed to aid strip mining and reclamation work. The latter are especially suitable for the many small operators (Tennyson, 1962).

A young man who has just joined a strip-mine organization urgently needs more information. Where can he get it? The time has arrived to start a scientific analysis of strip mining in order to bring about further development in the right direction. This analysis might mean new knowledge even for those who developed the empirical practices of the present. Additional training of the men active in mining operations would bring benefits to both the mining companies and the miners themselves.

But what can be done during the mining process to improve reclamation? Some people have answered, "Not very much." But during my trips across Ohio, Pennsylvania, West Virginia, Kentucky, and Illinois, I saw so many out-

EXPLANATION OF FIGURE 1

FIGURE 1. Mining methods favoring reclamation.

- A Long ridges with gently sloping valleys between them instead of high peaks and deep valleys make grading less expensive and reduce compaction of graded spoil. Ohio Power Co., Ohio.
- B Upper part of last cut by dragline is put on top of highwall and can be used for covering toxic layers above coal seam, when ponding is not possible. Kylertown Operation, Pa.
- C Adequate clearing of land before mining saves timber and facilitates work of excavators. Ohio Power Co., Ohio
- D Highly productive alfalfa stand on carefully strip-mined area. Note access road to "undisturbed old fields" on top of hill. W. Compton, Dole, W. Virginia.
- E Topsoil management often increases value of area for housing development and use for crop land. Teramana Brothers near Steubenville, Ohio.
- F Covering of toxic gob with fertile overburden in foreground right decreases water pollution and makes area plantable. Ohio Power Co., Ohio.

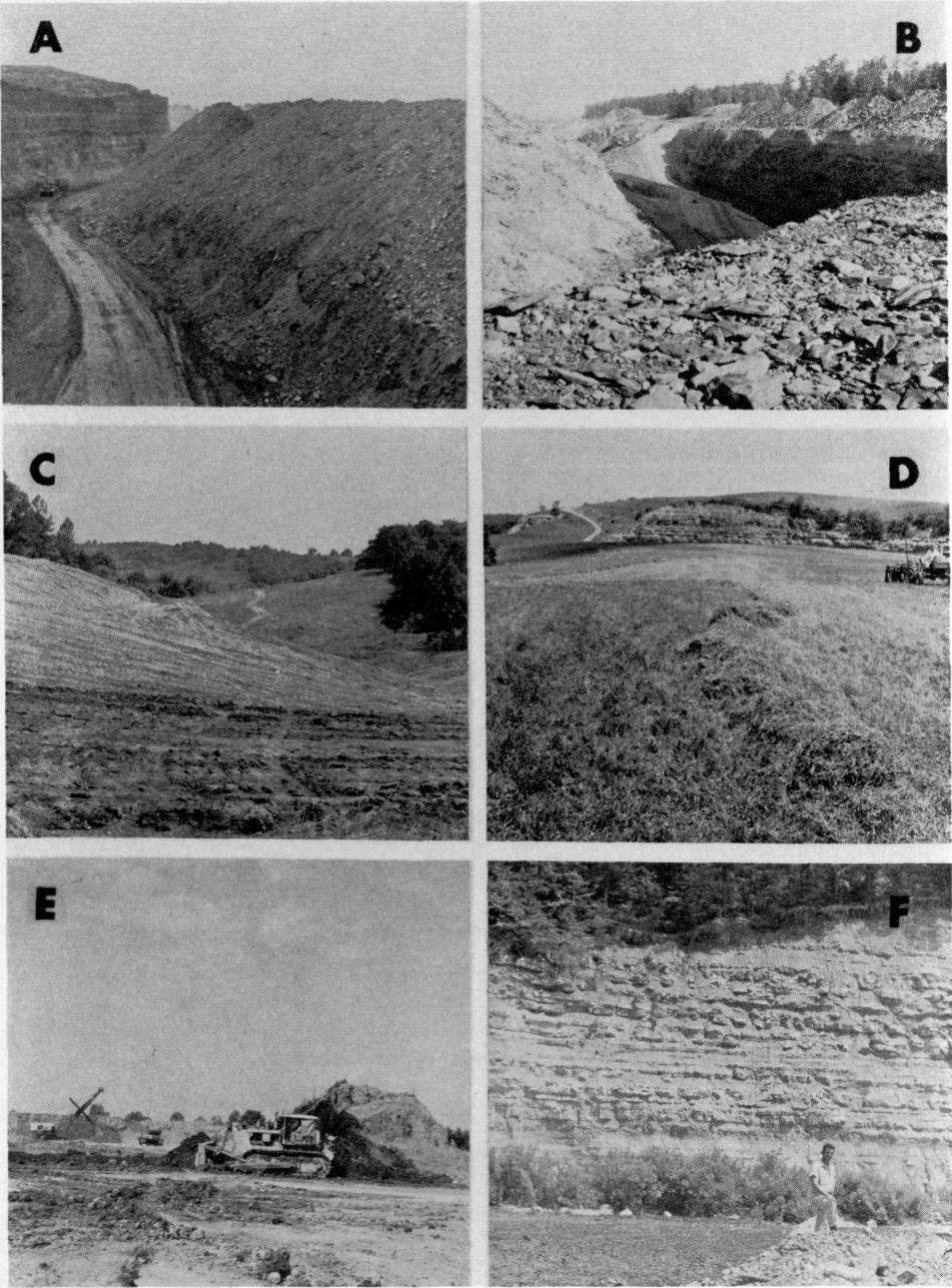


FIGURE 1

standing examples of good reclamation that I would say just the contrary: "Very much."

So far, I see only two factors which militate against a broad application of the methods that you have developed:

1. The difference between the present costs of reclamation and the present value of land, since the United States is still in the happy position of having an agricultural surplus instead of the famine to which more than half of mankind is subject.
2. The failure to preplan reclamation before the excavators start to cut.

In many cases, this preplanning can increase the value of an estate without any additional costs. Sometimes you can even save money by preplanning. I want to mention two examples.

The Ohio Power Company has started a careful disposal of overburden in such a manner that the spoil banks consist of long ridges without steep valleys between, instead of the old high peaks (Fig. 1A). By this method, the costs of leveling by bulldozers have been reduced. Less grading means also less compaction of the spoil and better growth of trees.

I saw the other example in Clearfield County, Pennsylvania. William Jones originally threw the upper layers of the last cut of the dragline onto the top of the high wall. Later, he pushed this down and buried the coal seam and the toxic layers without trouble. Thus he followed his motto, "Coal for today, timber for tomorrow," and also obeyed the Pennsylvania law (Fig. 1B).

PREPLANNING OF RECLAMATION

It has been stated that preplanning is one of the most effective means of improving reclamation. I am glad to find the importance of advance planning of land restoration confirmed by the "Mined Area Restoration Committee" of the Soil Conservation Society of America (Pyles, 1962).

Proper preplanning of reclamation involves many different considerations: previous and intended future use of the strip-mined land and the surrounding area, topography, agricultural value of the overburden, available mining equipment, degree of grading, costs of reclamation, economy of the area, and legal requirements. The planning of future land use depends not only upon the physical facts of a given case, but also upon the wishes of the land owner, the desires of the affected community, and the strip-mine law of the state.

Preplanning of reclamation can be done in different ways. One company will evaluate every part of its contemplated mining technology by its effects on land use after mining, and will change its technique if it interferes with this use. Another company will go still further, starting with the future land use and looking for the best way to combine this with coal production.

Let me simplify and outline the practical planning by some questions:

What kind of land use has to be restored?

Does a mixture of all layers of overburden allow such use, or is the separation of any layer necessary either for post-mining land use or for preserving water supplies?

Which kind of equipment is the best to get the coal and accomplish the other objectives?

What degree of grading is necessary?

What shall be done with the open pits?

These questions are very general; now let us go into detail.

OVERBURDEN CLASSIFICATION

Preplanning of reclamation always should start with the investigation of the spoil characteristics. Fortunately, the influence of overburden on reclamation has been well studied in the United States. These studies show particularly the

undesirable consequences of exposing pyritic material on both plant growth and water purity (Limstrom, 1960; Braley, 1954; Brant and Moulton, 1960; I got an interesting manuscript from Granville Smith dealing with this question). The geologic and economic conditions in this country are different from those in Germany; hence, the classification of overburden shown in my report from Germany must be changed.

Sterile or barren material, that is, nontoxic material with no nutrients or very poor water capacity, is almost unknown here. Material usable for agriculture can be divided into: material which, after weathering, has no rocks and can be plowed and tilled like an old field (AC); and other calcareous material which is well adapted for pasture but has too many rocks for mechanical equipment (AP). Thus we arrive at the classification shown in table 1.

TABLE 1
Classification of Overburden with Respect to Reclamation

| Value | Class | Usability for Crops | Examples |
|-------|-------|-----------------------------------|---|
| I | AC | Good for agriculture—cropland | Topsoil, loess, glacial till, soft shales |
| II | AP | Good for agriculture—pasture only | Calcareous rocky material |
| III | F | Usable for forestry | All other nontoxic layers |
| IV | T | Toxic | Sandstone and dark shales with pyrite |

You could also express the quantities of calcareous or pyritic material by a positive or negative index, showing the content of calcium or sulfur. Thus AC_{20} would mean that there is 20 per cent of unneutralized calcium carbonate ($CaCO_3$) in the overburden. T_{-10} would mean that there may be as much as 10 per cent of potential unneutralized SO_4 (all sulphides and pyrite expressed as SO_4) in the layer. Since the molecular weights of $CaCO_3$ (100) and SO_4 (96) are very close together, this would make it possible to estimate the composition of the mixture produced by a power shovel if the thickness of both layers is known. The amount of calcareous material should be at least two to four times that of the pyritic material. Further investigations are needed to determine which relations are still acceptable.

If topography, climate, or economic conditions prevent any agricultural use, classification is much easier. The overburden is divided into two classes only: nontoxic (F) and toxic (T) layers.

MINING METHODS FAVORING RECLAMATION

After thinking about the best way to explain improved mining methods, I conclude that I should start with my various observations in your mines and ask in what other places these or alternative methods are suitable. Table 2 will help us avoid loss of perspective.

Conscientious mining starts with the proper use of things on the surface, merchantable timber in particular, rather than with the coal. Hugh B. Montgomery (1962) mentions the adequate clearing of forest stands, not only in the coal-bearing area but also at the toe of the spoil pile, where slipping and erosion might waste valuable timber. I saw such clearing on coal fields of the Ohio Power Company (fig. 1C).

TABLE 2
Characteristics of Mining Methods

| Desirable | Undesirable |
|--|--|
| a. Clear-cutting affected timber | Leaving timber in the line of first cut. |
| b. Preservation of old fields not underlain with coal from unneeded disturbance | Thoughtless excavation or dumping outside the pit |
| c. Continuous ridges without deep valleys | Steep independent peaks, deep valleys |
| d. Good accessibility | Poor accessibility |
| e. Leaving most fertile spoils on the surface | Gob and toxic spoils on surface (dragline operation) |
| f. Covering coal seam and toxic part of highwall in last cut | |
| g. Ponds in last cuts where there is no danger of slides | Ponds in areas apt to slide |
| h. Mining of entire hills in one operation; where possible, changing from contour mining to wholesale mining of the area | |

Great areas can be saved by careful planning of the first cut, and by painstaking handling of the coal refuse and other debris. Frequently, much land is wasted by thoughtless dumping outside the pit.

I have already mentioned the careful dumping of the Ohio Power Company, which prevents high peaks and makes grading much easier (fig. 1A). These long ridges and the shallow valleys between them should be distinctive marks of progressive mining throughout the country, except where they are prevented by great differences in the height of the overburden or the need of gaps for haul roads.

A very important factor is the accessibility of both the old fields on the top of the high wall and the banks themselves. Figure 1D shows one good example from West Virginia. The access roads must be not only built but conserved. This calls for drainage and covering with durable material. Pyritic coal waste or shales are not at all suitable, because they affect water supplies. I hope the study of R. May, at Berea, Kentucky, will bring new knowledge about this matter with respect to areas having steep topography.

Next in turn are my observations on special management of the topsoil or fertile layers. I was astonished to find many examples of topsoil management in Ohio, especially in Jefferson County. Reading American laws and publications at home before my trip, I had not expected this.

I looked for the reasons and found two. In some cases, the mining company itself had a financial interest in restoring valuable land for housing developments (fig. 1E); in others the landowner had not sold his land but only the coal, and demanded full restoration, including full or partial backfilling of the highwall and spreading the old topsoil on the surface of the spoil banks.

Figure 2 shows one possibility of this kind of management. Bulldozers or scrapers take the topsoil and carry it to the toe of the intended first cut or anywhere outside the affected area before spoil disposal is begun. This seems possible in small operations only, because long haul roads mean very high expenses. If the state or federal government owns the land, it can demand topsoil management even for forests; this is done by the Wertz Coal Company, in Pennsylvania, in operations having highwalls up to 70 ft (Montgomery, 1962). But the demand of any landowner should be based upon the economic situation. He has to compare the difference in value of spoil banks of mixed overburden and those covered with a layer of fertile spoil or topsoil. If the mixed spoil meets all the needs of

the intended land use, then I cannot see any reason for spending money on spoil segregation. The greater the difference between the quality of mixed and covered spoil banks, the more advisable is a careful consideration of the technical possibilities of segregation.

Stock piling the topsoil outside the pit always means double movement—once before, once after mining. Hence, every operation that leads to immediate transportation of the layer to the final place of disposal, either a graded or non-graded part of the spoil bank, is to be preferred.

Motor graders could do this job on flat areas, but that would call for quite another kind of mining—shorter strips or pivoting operations. The direct transporting of topsoil without stock piling cannot be done without access way from the top of the excavatory side to the surface of the spoil banks. But even then, long haul roads mean high costs. It would be much better if the excavators themselves could care for the segregation and dumping of the fertile layers.

TOPSOIL MANAGEMENT

WITH **BULLDOZER** OR **SMALLER DRAGLINE**. [SCHEMATIC.]

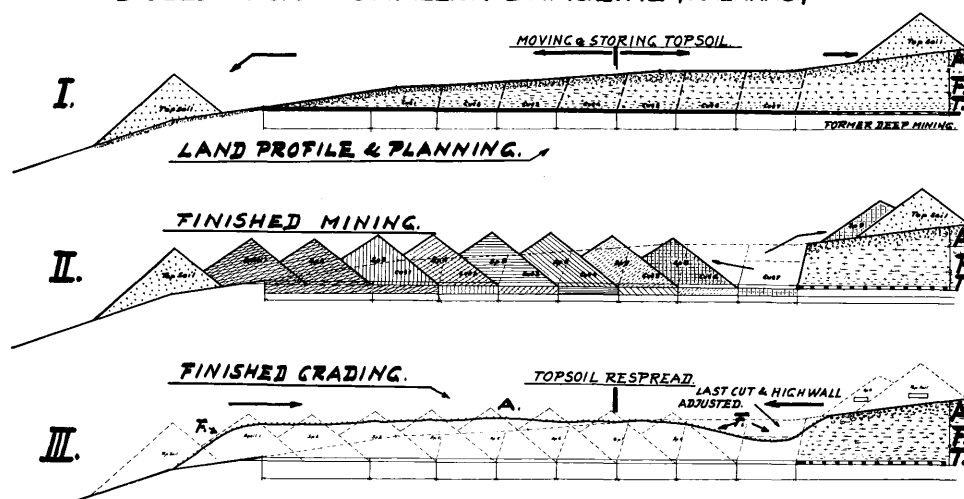


FIGURE 2. Topsoil management by combination of bulldozers or motor graders and dragline. Examples of this kind of operation are found in Jefferson County, Ohio for agricultural reclamation and housing developments.

The huge size of present-day excavators makes pure topsoil management impracticable and requires the inclusion of fertile deeper layers for segregation. (We call this "cultivated soil management" in Germany; it is not "cultivated soil" but "cultivable spoil.") Power shovels are not adapted to this procedure. Every cut mixes some or all layers of the overburden, resulting in mixed spoil banks that can be used for forest or pasture, if there is no excess of pyritic material.

Draglines do not mix all layers together as power shovels do, but cut one horizontal layer after another. This could be used to segregate the topsoil or bury the toxic material, but in practice it has meant mostly the contrary, i.e., spreading the toxic layers from above the coal seam on the top of the spoil bank. This practice could be changed. It is feasible to dump the best spoil material on the top. There are difficulties only if the dragline has already used its widest dumping radius or if the same material must be moved twice.

The bucket-wheel excavator can segregate fertile layers much better than even

the dragline. Its drawbacks have been its restriction to softer material and the need to clear timber and stumps before it is used (Lauchhammer, 1962). Mike Geller, of the Wellman Engineering Company, summarized his experience for me: "The bucket wheel can dig the same material as a shovel can without blasting. But the shovel can take bigger pieces."

The engineers of Krupp give a different report: they have stated that bucket wheels can even cut off regular banks of very hard sandstone, but are not suited for irregular mixtures of hard rocks and softer material. Krupp has now built a two cubic-yard bucket wheel for the Peabody Coal Company, which will handle 100 ft of unblasted overburden, including hard layers of sandstone (fig. 3). The required digging rate is 3,250 bank yards an hour (Petry and Schellhorn, 1962).

Bucket wheels are supposed to provide a way of segregating fertile layers under overburden conditions similar to those of Braidwood, Illinois. But I must point

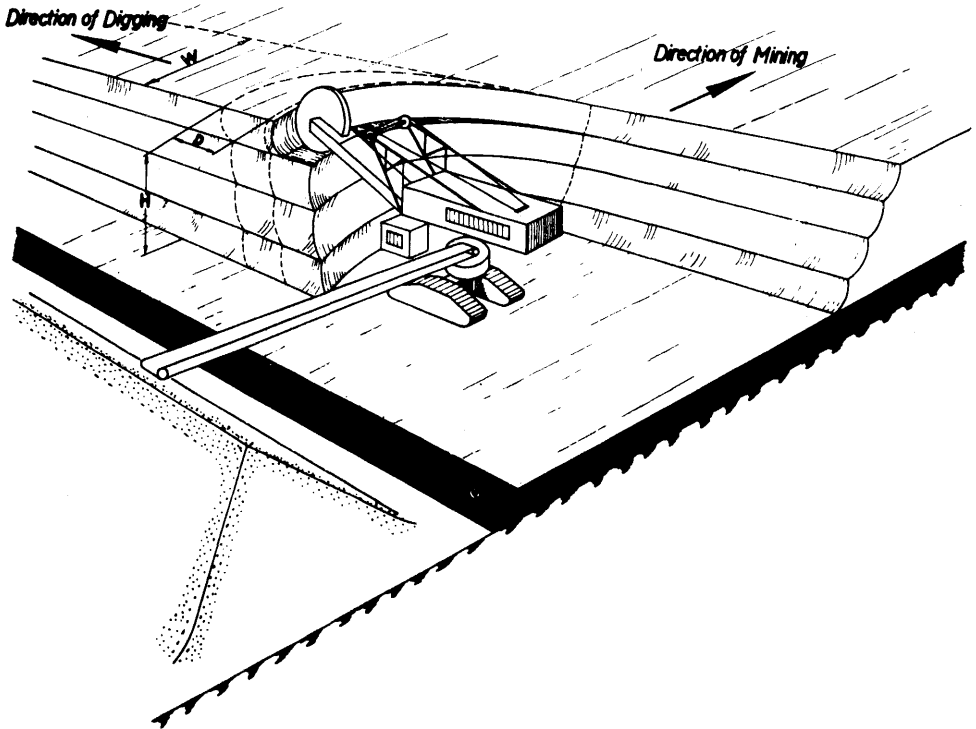


FIGURE 3. Benching operation of bucket-wheel excavator designed for Peabody's Northern Illinois Mine, Braidwood, Illinois, to remove 100 ft of overburden, including hard layers of sandstone. The machine cuts one bench after the other, swinging the wheel between the old high wall and the new one and moving back and forth on its crawlers. It can also work by the falling-cut method.

out that separate dumping depends on an additional length of the dumping boom to spread the upper layers on top of the spoil bank.

The next possibility would be a tandem operation. The upper excavator can be a dragline or a bucket wheel, either of which has a wider radius for spreading than a shovel of the same size. The shovel usually has to cut the rocky material of the lower layers. This practice is in common use in Fulton County, Illinois, where it was introduced by the United Electric Coal Companies. The 2.5 cubic

yard Kolbe wheel, conveying 3,500 cubic yards an hour, handled the unstable glacial drift, cutting and displacing it far enough from the open pit to prevent slides. The power shovel took large bits of the hard rocks below. I saw both machines traveling side by side on the coal in the Cuba and Buckhart mine (fig. 4).

The same good results were reported from the River King Mine, in Illinois, where a 2.5 cubic yard bucket wheel with a capacity of 2,175 cubic yards an hour assists the 70-cubic yard stripping shovel (Anonymous, 1960).

The covering of toxic layers by nontoxic material improves not only the site conditions for plants, but also the quality of the runoff and the ground water. Spreading of fertile spoil on dumps of "gob," the debris of old underground mining, makes plantable areas and diminishes water pollution (fig. 1F). Another possible improvement is to cover the open coal vein and the toxic part of the high wall. This is especially important if deep mining holes run into the pit. Whether the isolation of the pyritic material of the high wall can be done better by water, as prescribed in Ohio, or by spoil material as in Pennsylvania, depends upon the geo-



FIGURE 4



FIGURE 5

FIGURE 4. Tandem operation of bucket-wheel and power-shovel excavators in Illinois. The bucket wheel removes the unstable glacial till above, and the shovel handles the hard rock layers below.

FIGURE 5. Good growth of crown vetch on calcareous clayey spoil and good cooperation between The Hanna Coal Company and The Ohio Reclamation Association. The figure shows the two most essential things for any reclamation: suitable plants and capable men to do the job.

logic conditions. Water is a better isolating medium than spoil, but steep slopes, impermeable clayey layers under the coal, and inclination of the layers toward the slope may cause slides and prevent ponding. The variations of geological conditions make any general prescription or recommendation difficult. Grading loose coal, mine refuse, and other debris on the bottom of the last cut before flooding is one of the few recommendations that can be generalized. But I do not want to suggest any general grading of the high walls. Backfilling or grading of high walls is an esthetic problem rather than an economic one; so a foreigner ought to be quiet.

Last but not least, I want to mention a proposal of Paul Koller concerning the general shape and form of opencut mines. The usual practice in hilly topography is to strip on the contour until a certain height of overburden is reached; this height is determined by the dumping height of the equipment or economic considerations

involving the ratio of coal to overburden. Strange figurations of undisturbed land and long curved haul roads are the results of stopping at a definite contour line. Frequently a second operation using bigger machines follows some years later. Starting the operation on those hills where extensive mining is possible with present-day equipment would make possible shorter haul roads and eliminate the high-wall problem. That would mean encouraging strip-mining in flat and gently rolling topography and reducing it in steep topography, where damage to the land can be very serious (Collier et al., 1962) (fig. 6G and 6H).

Accelerated use of lignite resources in the western region of the United States could be part of such a program. Meanwhile, there is hope of developing equipment with which coal seams in steep topography can be mined without harm to the surrounding landscape.

GRADING

Grading is not only one of the most important, but also one of the most controversial subjects in strip-mine reclamation (Limstrom, 1953; Bergoffen, 1962). Economic and biologic points of view seem to be incompatible. We have just learned from Gus Limstrom the bad effects of grading on the growth of trees. Some weeks ago I had the pleasure of accompanying him on a trip to his experimental plots in southeastern Ohio. The striking difference in growth on graded and ungraded banks was obvious. On the other hand, grading is necessary for post-mining management, especially for any further mechanization of forest-management operations. And you do need this mechanization. Since manpower is so valuable in the United States, you cannot work in the older fashion of European forestry, where they paid a laborer 20 cents or less an hour before World War II. You must have machines and you need manageable areas for these machines. Even the forester who has to mark trees for pruning or thinning will get tired after a short time if he has to climb up and down over the rough surface of an ungraded spoil bank.

We face a contradiction: on one hand, the fact of better growth on ungraded areas; on the other, the necessity of grading. What shall we do? I see three possibilities:

- (1) The first would be to look for trees that grow on graded spoil banks as well as on ungraded areas. The white pine partially meets this test: it shows less difference in height in the two locations than other species. But it is still not good enough. A broader test series with other soft-

EXPLANATION OF FIGURE 6

FIGURE 6. Necessity and methods of soil amelioration.

- G Eroded material from above blocks creek and wastes best farm land in valley. Route 2, Albany, Ohio.
- H Heavy gully erosion of toxic spoil bank, because plantings without amelioration had no success. Danger to surroundings and ugly appearance. Beasley, Meigs County, Ohio.
- I Hybrid poplars show better growth when underplanted with herby legumes, e.g., crown vetch (*Coronilla varia*). *Lupinus perennis* should be tried also. Blue Crystal Mines, Ohio.
- J Black locust is best native pioneer for building up of soil, but is often killed by borer and not adapted for mixture with many light-demanding trees. Star Mining Co., Ohio.
- K European black alder (*Alnus glutinosa*), best European nurse tree, grows pretty well on Ohio spoil banks. Note self-pruning of this stand, planted about 1956 north of Pomeroy, Ohio. Swisher Coal Co.
- L Shrubby legumes, e.g., autumn olive (*Eleagnus umbellata*) improve soil and wildlife habitat. They should be tried also in mixture with pines and light-demanding hardwoods. SCS Preston County, W. Virginia.

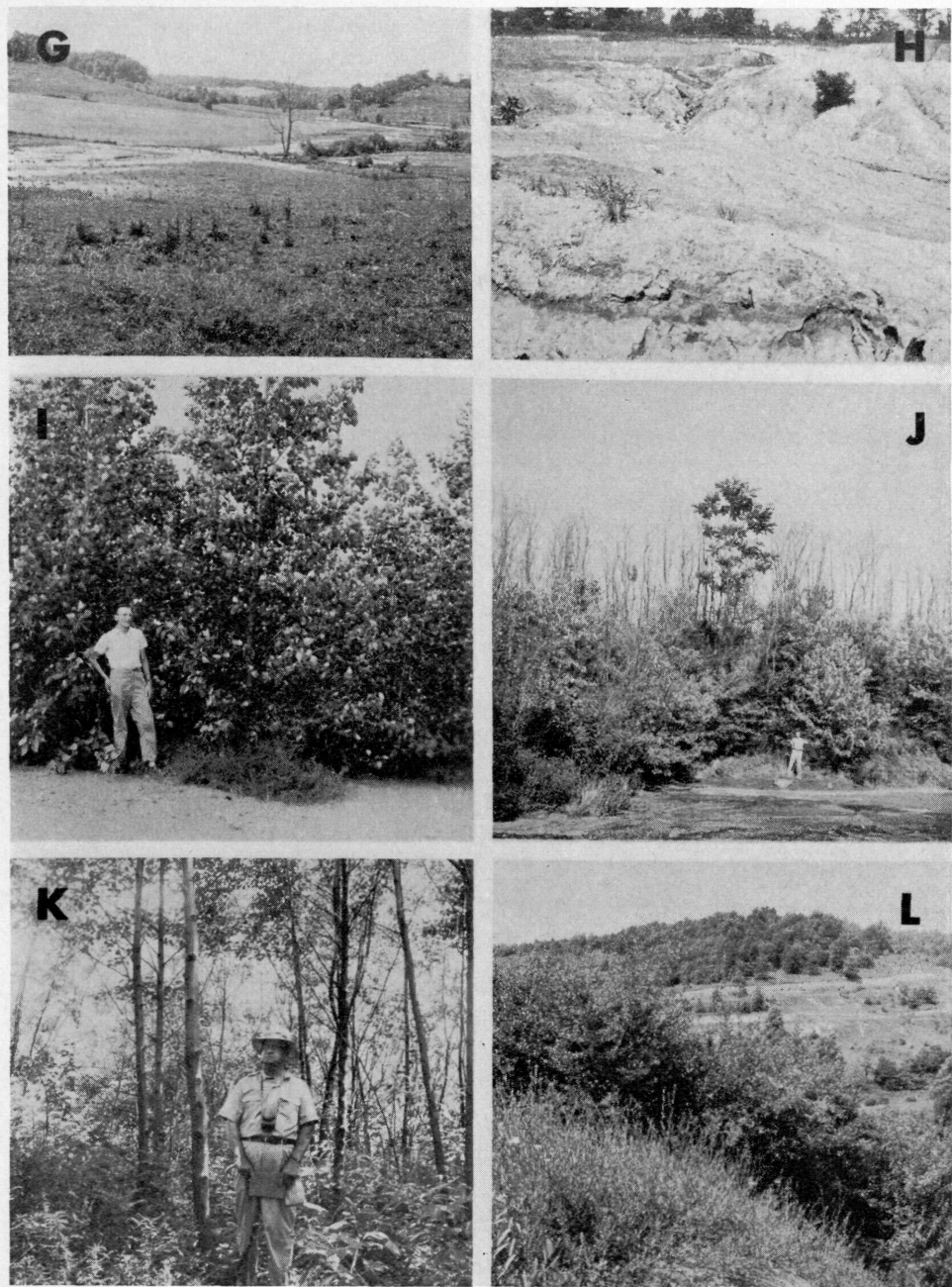


FIGURE 6

and hardwoods might produce better results. It would not be necessary to find a species that grew equally well on both sites. We might find one that grows on graded banks as fast as even the best species on ungraded areas. It would not matter if the first species was not successful on the ungraded banks.

- (2) The second way would be to eliminate the causes of bad growth after completion of grading. I am not sure that we know all of these causes. The principal one may be compaction, which includes reduced pore volume and crusting of the surface; this reduces aeration and infiltration. But I believe that there are other causes for the better growth of trees on short slopes. The water movement down the slope results in a better supply of water and nutrients to the roots. Moreover, running water always contains more oxygen than stagnant water. In later years, better light conditions on a rolling topography also can be an important factor.

We cannot eliminate all these factors, but we can determine which ones are the most effective and the means by which they can be influenced. First of all, we need exact figures about the degree of compaction and infiltration, and that calls for good physical methods of investigation. If we want to compare different spoil types, or methods of grading and loosening the spoil, vague estimates do not help very much. Second, since the final decision depends on the reaction of the plants, we have to test how they respond to our efforts. Let me mention some experiments which might be useful in this connection. Loosening of the compacted zones can be done by mechanical equipment. Iron ribbers can loosen even the subsoil, whereas, on most sites, breaking up a crusted surface is no problem. But the effect of mechanical loosening usually lasts only a short time. If settling of the soil is to be prevented, the plants have to make quick use of this period of better aeration. The permanent effect depends upon the vigor of the plants and animals in the subsoil, the stabilization of soil crumbs with humus, and the protection of the surface against siltation by litter or living plants.

Some of the good effects of slopes can be obtained by plowing open furrows or digging small depressions. The small differences in height result in better infiltration and aeration, and in a variety of water conditions; this in turn makes possible a richer soil life, comprising more species. The furrows also tend to increase storage of litter, which would be blown away from a smooth, bare surface.

- (3) The third way of solving the grading problem would be to use a technique that does not cause any compaction or other detrimental effect. The attainment of a lower degree of compaction than we now have would be an important forward step. This still has to be done. In my earlier discussion, I mentioned the grading plane which is drawn back and forth between two motorized winches. The small weight of this grader does not cause any compaction, but large rocks may prevent its use. A drag-line could have the same effect outside its moving road. Its bucket can level high peaks or ridges without any compaction, since, in comparison to a bulldozer, its weight is insignificant.

Crawler-mounted bulldozers with less soil pressure than the heavy rubber-tired ones that you now prefer could diminish the compaction. But I know that big excavators cut off big rocks and need big grading equipment. In this respect the forty-cubic yard motor grader may be helpful.

To reduce compaction, Tennyson (1962) recommended the use of motor graders, or at least a longer and wider track on the bulldozer to distribute the weight over a larger area. The development of new grad-

ing equipment is the job of the manufacturing industry. I think your engineers will become interested in this problem if you put the question again and again. And I hope they will find a feasible and economic solution. I still have in mind the words of G. Tennyson: "The equipment is the key to the reclamation problem. It must be cheap to purchase, cheap to operate, and must be able to do several jobs in the mining operation so that the operator can make his profit."

Having discussed the technique of grading, we should turn now to general principles bearing on the subject. We should not grade more than is necessary for good post-mining land use. As you all know, cropland needs more treatment than pasture or woodland. As I explained earlier, careful spoil disposal which avoids great differences of height between ridges and valleys will reduce the repeated use of grading equipment at the same spot.

Let us note one economic consideration. Careful grading in order to avoid compaction, the limiting of grading to dry periods, or the use of special machinery will often cost more than the usual practices. In areas where there is no damage by compaction, such unusual practices are not needed. They seem to be necessary only on spoil material which is highly susceptible to compaction and siltation, such as calcareous clays. Further investigation is needed to determine the regional limits and the extent of the damage from various practices, as a base for operational decisions.

REVEGETATION

In the field of revegetation of spoil banks, American scientists have done so much research that all other countries, my own included, seem to lag behind this one. Instead of talking about theories, they have made numerous trials and investigations, which have provided a broad base for practical revegetation. Most of the publications named in the bibliographies of Limstrom (1953) and Funk (1962b) are related to this phase of reclamation. A comparison with the European publications collected by Drlik (1957) and Knabe (1957) shows greater attention to technical questions there.

Still more convincing than books and good papers are the revegetated spoil banks of Ohio themselves. The good results represent the successful work of the Ohio Reclamation Association and many mining companies.

AGRICULTURAL RECLAMATION

On one of my last days in America, I got my deepest impression concerning agricultural strip-mine reclamation. It was near Cadiz, on my visit to the Hanna Coal Company. The extensive use of crown vetch, its amazing ability to improve soil on calcareous clays, and its high value as a forage plant should be known in all mining districts having similar spoil and climatic conditions (Fig. 5). But Ed. Mills, of Cadiz, Ohio, can explain its use better than I can.

I saw good alfalfa stands in West Virginia (fig. 1D), fine corn fields in Illinois, and good grass-legume mixtures in many places in Ohio. These mixtures seem to be better adapted than pure alfalfa for mixed spoil. I did not see a direct comparison with crown vetch on such material, so I cannot give detailed recommendations on this point.

The farmers in the auditorium will ask me: Why does he say nothing about farming on strip-mined areas? The reason is very simple. A short visit to a mine does enable the visitor to recognize the kind of mining and to judge the growth of trees representing the sum of good and bad years in comparison to other mines. But such a short visit, in such a dry year as 1962, does not provide an accurate picture of the normal height of the crops.

Here you must find your own way. You may examine the results of German trails to loosen the subsoil after compaction. You can also try mole drainage,

following English experiments. The necessity of enrichment with humus is well known on both sides of the Atlantic. The best plants and management practices may be similar. I wonder if you tried also to seed grass, not in the first, but in the second or third year of an alfalfa stand. But any further suggestions need a longer period of study than I had this summer.

AFFORESTATION OF SPOIL BANKS

The forest-research program of the United States on strip-mine reclamation is one of your best and most successful programs. The different studies in the Central and Northeastern states have shown the way to replant 90 per cent of all your spoil banks successfully. The mixture with black locust has improved the site conditions much more than anybody would have thought possible thirty years ago. Large-scale trials with many other native and some foreign trees have shown which are the best ones for various site conditions. Two major problems remain. The trials showed hardly any species suitable for planting of toxic spoil banks having a pH-value under 4.0 (Limstrom, 1960), and the rate of tree growth on graded calcareous clays did not satisfy the industry that has to pay for the afforestation (Hyslop, 1961). A higher production of merchantable pulpwood and timber per acre is still a desirable aim of forest research.

PROBLEMS OF AFFORESTATION

Now let me make some suggestions for solving problems of afforestation.

Broad use of poplars.—Recent investigations of strip-mine plantings in Ohio have revealed the excellent growth of both cottonwood (Limstrom, 1960) and some hybrid poplars (Funk, 1962a). These, together with successful plantings in Pennsylvania (Hart and Byrnes, 1960), confirm the favorable German experience with selected hybrid poplars on spoil banks. I dare to recommend, therefore, a much broader use of poplars in Ohio in order to reach the desired higher yields. The pulp and paper industry will welcome this.

I suggest a threefold program:

- (1) Large-scale planting of those poplar clones, possibly in mixtures with legumes or alder, which have proved best on the experimental plots. Clone 312 with good increment and no canker is one of these (Funk, 1962).
Hybrids of the Aigairos section and the indigenous cottonwood prefer well-drained loamy soils above pH 5, while hybrids of balsam poplar and large-toothed aspen grow on more acid banks (fig. 6I). The native cottonwood and large-toothed aspen should not be forgotten in strip-mine reclamation. I saw excellent trees of the latter species pioneering in many acid spots, but no artificial planting.
- (2) Small test plantings on different spoil types with all clones available that do not suffer from disease. Bad failures with fast growing but susceptible clones like *robusta* or *brabantica* in Europe should make us cautious about all varieties which are not resistant to canker or dothichiza (Mueller and Sauer, 1957-61). You should not be disappointed if only one clone out of hundreds satisfies your expectations. This clone can be planted on thousands of acres later on, whereas one should prefer mixtures of different clones. Langner (1963) found some clones successful even on poor sands from hydrologic transportation, where all the others disappointed. The Italian strains "Jacometti 78," "172," and "J 214," and Wettstein's crossing "W 80/31/15" and "W 80/30/26" also are among the clones which could be tried in Ohio.
- (3) Selection of promising trees of cottonwood and large-toothed aspen, their vegetative propagation, and artificial crossings between and within the different species of poplar. That is a matter of plant breeding, but the results will help strip-mine reclamation, too.

Use of nitrogen-fixing plants. Nitrogen is one factor which is minimal on strip mines. To meet this lack you have undertaken the locust plantings and are now trying the European black alder. Beyond this, David Funk, of Athens, Ohio, is now starting an experiment with all available species of alders. I welcome this study, and will suggest a similar experiment on German spoil banks. Heitmüller (1962) already had started similar trials on forest sites. But I would go still further. The high damage caused to the black locust by the locust borer and the ugly appearance of this tree after the attack of the leaf miner seem to be at least partly a result of too extensive planting of the species. Nature usually reacts negatively when man favors one tree species alone. Therefore I want to encourage you to leave the one-way street of soil improvement by locust alone, and to use a four- or six-lane highway—namely, different mixtures with all kinds of nitrogen-fixing plants.

Studying the many experimental plantings which are the fruits of good cooperation between the coal industry and forest-research stations in Ohio, you can observe the following groups of non-nitrogen fixing trees on spoil banks. They are classified here according to rate of growth and light demand.

- (1) Very fast growing hardwoods, light-demanding, growing as fast or faster than the black locust and European black alder: e.g., hybrid poplar, cottonwood, aspen, large-toothed aspen. (On some sites, poplars belong to group 2.)
- (2) Light-demanding hardwoods, not as fast growing as black locust and alder: e.g., sycamore.
- (3) Shade-bearing trees, slow growing: e.g., sweet gum.
- (4) Fast growing softwoods: e.g., Japanese larch.
- (5) Softwoods with slow growth in the first years, light-demanding: e.g., most pines.

This classification is simplified. There are intermediate groups: e.g., tulip poplar between 2 and 3.

On the other hand, you have four different groups of nitrogen-fixing and soil-improving plants:

- (a) Black locust: fast growing, light demanding, subject to early breakdown on many sites by borer attack, root sprouting (fig. 6J).
- (b) European black alder: fast growing, shade-bearing, breakdown not yet known, no root sprouting (fig. 6K).
- (c) Nitrogen-fixing shrubs: prostrate locust, autumn olive (fig. 6L), Japanese lespedeza, false indigo (on calcareous spoil only).
- (d) Nitrogen-fixing herbs: Sericea and Korean lespedeza, crown vetch, perennial lupine, sweet clover (fig. 6I).

A testing of further nitrogen-fixing trees, such as other species of *Alnus*, will extend this list. At this point, let me present some experiences with two European plants: alder and perennial lupine. I was glad to see that the Ohio Reclamation Association had used the alder seed I had collected on a Lausitz spoil bank to produce some very fine plantations. One of the oldest is situated near Pomeroy, Ohio (fig. 6K). There the alders have grown even faster than the black locust near by. Straight stems which have started self pruning promise good crops. The soil seems to be improved by rich litter production. Altogether it is a very promising pioneer tree for spoil banks, having been used with good results in Europe from Poland to England, and from Denmark to southern Germany. But I want to warn of the danger that an excessive use of this tree uncombined with other species may bring about, leading to failures and disappointments comparable to those with the black locust. A mass planting will favor its enemies too much. Many trials will have to be made to prove the suitability of this species to the various site conditions and mixtures. It seems to be well adapted to acid shales, but not to calcareous clays; it might still penetrate acid loamy clays. Lowry,

Brokaw, and Breeding (1962) have collected recent information about this species on Ohio spoil banks.

The experiments with other alders from East Asia, Europe, and America that have been planned will reduce the tendency to plant just this tree or black locust. For calcareous spoil material, the European speckled alder is a better pioneer, but it shows the same root sprouting as black locust and its wood has less value than that of black alder.

Let me finish this section with some remarks about perennial lupine. Like broom, yellow lupine, and sweet clover, it is a soil-improving plant, suitable for German clear-cut areas or wastelands. It is used much more than all other legumes together. It prefers loamy soils and pH values from 5 to 7, but shows good results on sands with little loam content. It improves degraded soil within a few years and favors the propagation of the earthworm. The forester likes it for its relatively mild competition with forest seedlings, if the proper planting distance has been observed. It is easy to control. One footstep breaks the stalks down, and a second growth after mowing does not reach the vigor of alfalfa or crown vetch, either of which can provide vigorous competition with forest plants.

Industry has asked for higher yields of pulpwood or timber on spoil banks (Hyslop, 1961). One silvicultural answer to this question consists of mixing the right groups of crop trees and nurse crops that I have mentioned. To get the best mixtures, we need to learn which trees and soil-improving plants do best together. Table 3 will explain my ideas briefly.

TABLE 3
*Examples of Possible Mixtures Between Crop Trees and Nitrogen-Fixing Plants
for Trials on Spoil Banks*

| Crop Tree | | Nurse Crop | | Mixture Proved Successful | |
|-----------|------------------------|------------|------------------------|---------------------------|------------|
| Group* | Representative Species | Group* | Species | In Ohio | In Germany |
| (1) | Hybrid poplar | b | Alder | | + |
| | | c | False indigo | | |
| | | d | Crown vetch | + | |
| (2) | Sycamore | c | Autumn olive | | |
| | | d | Sericea lespedeza | | |
| (3) | Sweet gum | a | Black locust | + | |
| | | d | Korean lespedeza | | |
| (4) | Japanese larch | b | Alder (one year later) | | + |
| | | c | Prostrate locust | | |
| | | d | Perennial lupine | | + |
| (5) | White pine | c | Prostrate locust | | |
| | | d | Perennial lupine | | + |

*For explanation of groups, see text.

These proposals are not intended as planting guides for wide use, but rather suggestions for new experiments on limited areas by professional foresters. Therefore, it will be enough to name one species for each group. The strip-mine expert can easily complete the list. Nevertheless, some comments about these representative mixtures seem appropriate.

The groups of crop trees listed here are based on rate of growth and light demand. The experimenting forester has to observe all other qualities of each species of crop and nurse-crop trees: e.g., the pH value. Both hybrid poplar and false indigo do well on calcareous or neutral, well drained spoil, whereas white pine and perennial lupine grow well on fairly acid spoil of about pH 5. But now to the detailed comments.

Group 1: *Very fast growing, light-demanding hardwoods*

Some hybrid poplars have such a fast youth growth on suitable sites that, theoretically, we could mix them with any nitrogen-fixing plant. We can find good examples of mixtures even with black locust in Germany (Knabe, 1963, table 4). But a mixture of two species with high light requirements is not the best solution; sometimes it results in severe competition. Hence, I did not mention this mixture (which would be 1a in the table).

A mixture of hybrid poplar with alder has been the principal type of strip-mine afforestation in the Rhineland. The shade-bearing alder prevents a dense grass vegetation which would harm the poplars. If the poplars are growing more rapidly than the alders, these can tolerate the shade and help the self-pruning of the poplars. On sites where the alders grow better and tend to overtop the poplars, wider spacing of both species, planting the alders one year after the poplars, or early thinning can help. But I believe that in many cases a mixture with nitrogen-fixing shrubs or herbs will be the better solution. The false indigo cannot be planted except on calcareous spoil; autumn olive or prostrate locust would grow on a wider variety of sites. The first prostrate locust was found by R. Mingus on a spoil bank of the Ohio Power Company and propagated at the Ohio Agricultural Experiment Station at Wooster (Kriebel, 1960). All these shrubs have proved their suitability for Ohio spoil banks, and for some in West Virginia and Pennsylvania too. But I do not know of any plan to mix them with poplar; we need experiments along this line.

Mixture with leguminous herbs should be done much more widely. The first experiment with planting crown vetch under MacKee hybrid poplars on acid shales, initiated by O. D. Diller at Wooster, has been a complete success (fig. 6I). But other herbs, perennial lupine at least, should be tried in the same way.

Group 2: *Light-demanding hardwoods, not so fast growing as black locust*

Sycamore is a fast growing pioneer on spoil banks, but it cannot withstand the shade of interplanted black locust. I fear similar bad results in mixtures with alders.

Sycamore seems to be ideal for a mixture with nitrogen-fixing shrubs. Which shrub will be the best has to be determined. In the same way, herbaceous legumes could favor the development of the sycamore. Sericea and Korean lespedeza, and perennial lupine are worth a try. Crown vetch might be too competitive. I saw one area with poor survival of the trees on clayey No. 8 spoil, but I do not know the history of this plantation and so suggest further experiments.

Group 3: *Slow-growing, shade-bearing trees*

Sweet gum is the representative species for Group 3. Many mixed plantations with black locust have proved the suitability of this mixture (Limstrom, 1960). Sweet gum is very shade resistant and does well even before the breakdown or the harvest of the locust.

The slow rate of growth of sweet gum in its youth makes it a dubious choice, if mixtures with alders or shrubs are to be recommended, since the shade of these may be denser than that of the locust. Broader spacing or mixtures with herbaceous legumes should be tried. Proper distances between the rows of trees and the sown legumes are essential; hence you can hardly sow by airplane. Whether Korean lespedeza is the best herb for this mixture has to be determined.

Group 4: *Fast growing softwoods*

Larches are good pioneers on loamy spoil above pH 5. Failures with European larch are usually due to a bad seed source. Seed from higher altitudes of the Alps Mountains are not usable at all. The "*Sudeten*" seed source used to be the best

in Germany and Czechoslovakia. The growth of larches is increased greatly by the right mixture with nitrogen-fixing plants. Alder and perennial lupine have given good results in Germany. In Pennsylvania, I found good stands of pure European and Japanese larch; the first one grew better in the anthracite region. Tests in Ohio will be interesting. Japanese larch suffers under long droughts.

Group 5: *Light-demanding softwoods with slow rate of growth during youth*

Economically, the pines are the most interesting species, but their acid litter is bad for rebuilding new soil on spoil banks and their susceptibility to overtopping by black locust prevents their use in a mixture with this species.

In general, therefore, I would recommend planting pines on old fields or forest soils, and hardwoods on spoil banks. But the mixture of pines with herby and shrubby legumes might offer a combination of soil improvement and economic use. Black locust and alders would require too much pruning and thinning to prevent competition. The prostrate locust or perennial lupine, however, may be suitable. A few experiments on soil improvement by *sericea lespedeza* and orchard grass did not show convincing results (Finn, 1958). On one experimental plot on No. 8 spoil, I got a better impression by visual inspection. Further measurements and repetitions of these experiments will be interesting. I suggest, however, that grass mixtures be avoided because most grasses have a detrimental effect on trees.

The combinations listed in table 3, together with others not shown, provide wide opportunity for new trials, and thus for experience that we do not have in either Ohio or Germany. Such experiments should lead to the discovery of many more species that will not be as susceptible to disease and will bring higher economic yields.

AMELIORATION OF TOXIC SITES

The next topic is amelioration of toxic sites. In this country I found the general opinion that in time these poisoned areas will leach out, and hence, a lack of great enthusiasm for any kind of amelioration (Bergoffen, 1962). But there are two reasons why the job of amelioration should be undertaken. First, there are some toxic areas that are dangerous to their surroundings—streets, railway traffic, creeks, or the mine itself. With proper knowledge, these can be revegetated and the danger removed. Second, there are places that, though not dangerous, are ugly. People do not see all the places where your reclamation efforts were successful, because in many cases the appearance is not greatly different from that of the original landscape. But, unhappily, they will see every spot where you did not succeed, because it is so much uglier than its surroundings.

Let me give one striking example. Near Albany, Ohio, we met Mr. Woodrow Wilson. He used to grow 100 bushels of corn per acre on his fertile valley loams, the deposits of two creeks which met at a right angle on his land. But now his best land was wasted by deposits of fresh sand and silt (fig. 6G). What had happened? The slopes of both valleys upstream from his property had been strip mined and replanted according to law. But the plants died on the toxic spoil and huge masses of sediments were transported into the creeks (fig. 6H). The creeks filled their beds and blocked each other; large overflows and wasted croplands were the final results.

You will understand that a successful planting of the spoil banks after amelioration would have stopped erosion and inundation. This farmer is really interested in a practicable way of amelioration on those toxic sites. I will not repeat my general descriptions of proper amelioration given in the earlier session. I want only to stress the importance of the fact that the pH value is not sufficient to identify toxic sites or determine the amount of lime necessary for amelioration. The titratable free acid is a much better indicator; we need to know exchange capacity and base saturation also.

It is not always necessary to apply lime or fertilizers; sometimes a simple alteration of a uniform bad site works wonders. Let me give some examples.

Long soft slopes of erodible material are highly susceptible to sheet and gully erosion. The proper soil-conservation practice for such sites is contour-strip cropping or terracing, in order to reduce and slow down runoff (Kohnke and Bertrand, 1959). These methods work by variation of the ground cover or the slope. I was glad to see such terraces on spoil banks in Jefferson County. The value of growing patches or terraces on steeper slopes for the establishment of forest stands is well known, too.

I have observed efforts at amelioration of uniformly bad site conditions by simple alteration in three different countries. In 1951 Ballaschk (1955) showed me a toxic and water-repellent spoil bank in the Lausitz mining district. He had plowed open furrows and planted birches and European black alders in them. In spite of the very bad site, he succeeded: the roots got water and the bottom of the ditches was leached out.

In 1956 M. Holovsky (1953) showed me experimental plantings on toxic shales of an old sulfur mine near Pilsen, Czechoslovakia. Only birches survived when planted in open furrows.

W. Dietrich, of East Canton, Ohio, was the third man who tried this furrow planting without knowing what the others had done. He called it "corduroy grading" or "ridge grading." He had better success on those spoil banks than on flat graded areas of the same acidity.

After these favorable experiences on very acid spoil banks in different countries, I dare to recommend a broader application on marginal spoil. Extremely toxic areas will need additional lime and fertilizer, as reported from the Lausitz mining district. Not only acid, but also extremely alkaline soils can be improved by creating a ribbed instead of a flat surface. In 1956, B. Toth showed me Hungarian Szik soils with high content of salts, especially soda, in the B horizon. On areas where trees would not grow, afforestation became possible after plowing broad ridges. English oak and Russian olive grew on the top of the ridges, flat-rooting in the old A and the material of the filled A and B horizon. They showed still better and deeper rooting in the valleys between beyond the old B horizon, where the salt concentration did not reach the lethal degree. Liming with CaCO_3 and gypsum supplemented the mechanical improvement. Later on, he found even a good growth of poplars on such ridges (Toth, 1961).

I want to summarize. Whereas farmers try to make each field more and more nearly uniform in order to have the same conditions for germination, growth, and maturity, foresters can utilize the ability of trees to adapt to variations within a given site in order to promote better growth.

WILDLIFE, SCREEN, AND ORNAMENTAL PLANTINGS ON SPOIL BANKS

I have been much impressed by the great interest in wildlife in your country and the systematic efforts for the improvement of the habitat. On my trip, G. Smith, of Columbus, Ohio, was a good advocate for those ideas. Some sportsmen's clubs have purchased and planted spoil banks in order to provide better hunting. Scientific research helped them to find suitable plants for this purpose (Riley, 1957). A broader application of the available results on other spoil banks could have far-reaching consequences for wildlife development.

Economists sometimes overlook the importance of outdoor recreation and of beautiful landscapes. We all know that the anthracite region of Pennsylvania is a depressed area. When inquiry was made as to why attempts to attract new industry had had so little success, it was found that the ugly bare heaps of spoil and debris around many cities had frightened away investors and plant managers. The scouting manager or engineer might find a plentiful supply of labor, but be unwilling to move his family into such ugly surroundings. And so the plant went elsewhere—perhaps to Florida or California.

Both industry and the Forest Service have recognized these facts and have started "screen plantings" to hide the eyesores. Large-scale plantings of all the spoil banks and colliery waste tips will be the next step (Frank, 1958).

While traveling Ohio highways and back roads, I enjoyed the beautiful tiger lilies and multiflora roses, but outside of the settled areas, I missed other flowering shrubs and herbaceous plants. It is not enough to make spoil banks green; they would look much better if they showed a greater variety of colors. And we know enough beautiful plants to attempt to provide such variety. Spoil banks are new man-made lands, and man should help nature to greet us in full amenity.

GOOD MANAGEMENT

My last point is a general conclusion based on a comparison of 200 years of European forestry with strip-mine afforestation here. It is this: Artificially planted forest stands show trends of increment and development different from those of virgin forests.

If you have planted a spoil bank and want to get your money back from the economic yield of the stand then you must find the kind of management that will achieve this objective. This should be done in 90 per cent of all planted areas; some exceptions where no management is needed only prove the rule.

The general trend is in two directions:

- (a) Mass production of wood for container boards, pulpwood, etc.
- (b) Production of timber of high quality for saw logs and veneers.

The latter stands need careful control during their entire life. In the Vinton Furnace Experimental Forest, I saw good examples of this kind of research on undisturbed areas, conducted by B. Roach, of Athens, Ohio.

HUMAN PROBLEMS OF SCIENTIFIC EXCHANGES

The exchange of ideas and experience between different countries is an important factor in modern science. It can help us find better solutions for problems of strip-mine reclamation too. But such exchange is not only a scientific, but also a human problem.

If scientists hear that colleagues are working on the same problems in foreign countries, they show three different types of reaction.

- (1) Ignore

The scientist thinks: "I am not interested in the work of others." That sounds stupid, but it happens a thousand times a day. It requires effort to learn a foreign language and to use it for understanding other people, their problems, and their ways of seeking solutions. I was glad to discover that in America there is now an increasing interest in foreign languages, the basis for all international understanding.

- (2) Read and conceal

The man who does this eagerly picks up the ideas of others, changes them a little, or starts similar experiments; but he presents all results as his own findings. This poisons human relations and creates distrust.

- (3) Read, test, and give credit

The proper way is to study all the foreign efforts, determine which ideas or results are applicable to my special problem, and give credit to the original investigator. We cannot make progress by ourselves alone. If anybody helps us along the way we want to go, we ought to be thankful. Such an attitude detoxicates human relations, improves trust. The man who is appreciated for what he has done feels like a millionaire and will be glad to give credit to the work of others. And this stimulates a feeling of mutuality.

If we are sincere, we have to confess that we have been discussing, not three different types of men, but three different reactions of ourselves. We should

encourage the third, and suppress the former types of reaction. Two of the Ten Commandments may help us: "Thou shall not covet . . . anything that is thy neighbour's" and "Thou shalt not bear false witness against thy neighbour." Such a policy is not an obstacle, but a help for us; indeed, there is a high correlation between the ability to develop new ideas or discover the secrets of nature, on the one hand, and the love of truth, on the other. If we take foreign ideas and present them as our own, we shut the door to flashes of inspiration and block the springs of original ideas in ourselves.

SUMMARY

What is the aim of reclamation? We want to create productive lands and a pleasing landscape after the strip-mine operation is finished. What is the best way to achieve this aim? We have heard a lot of facts, observations, and recommendations. Let's look for what they add up to.

- (1) Mining and reclamation have to be an inseparable unity.
- (2) Reclamation has to start simultaneously with the plans for harvesting the coal. Only in this way can we attain the greatest success with a minimum of effort.
- (3) Reclamation is an economic matter. If there are different ways to reach the same objective, we always have to look for the cheapest way. Costs and results of reclamation have to be in proper relation. Our practices should be based upon a farsighted look into the future.
- (4) Reclamation is not only an economic matter. No nation has the right to waste land, given her by God. Facing the problems of hundreds of millions of starving people, we cannot continue the bad practices of the first half of this century.
- (5) And what is to be done now? First, let us compile and synthesize the available information about reclamation and improved mining. Then let us apply the methods that have been developed:
 - (a) By winning and preserving the voluntary cooperation of the mining companies. This is a psychological problem.
 - (b) By training miners, mining engineers, farmers, foresters, conservationists, and all other scientists in the different aspects of reclamation, so that each can understand the whole as well as his special field. This is an educational problem.
 - (c) By pre-planning reclamation and conscientious mining. This is a management problem.

Let us make further progress in research by good teamwork and by holding the best scientists who already have experience instead of using only young fellows until they have finished their Master's or Doctor's degrees. These bring new ideas, but frequently change to other jobs as soon as they have learned what to do.

If we work together, we can lift reclamation to a higher level, produce better economic results, and create new lands of which America can be proud.

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DISCUSSION*

P. E. HEIM:

- 1) What is the average thickness of the overburden?
- 2) What is the average thickness of the coal vein?

ROBERT M. REESER, *Columbus, Ohio*:

- 1) What is the typical thickness of overburden removed in brown-coal mining?
- 2) Maximum thickness?
- 3) What is the typical thickness of the brown-coal layers?
- 4) What is the minimum thickness of layer that can be mined economically?
- 5) Can you compare the price of brown coal in Germany with the price of coal in Ohio? In the U.S.A.?
- 6) Could you afford this kind of mining if the price of coal were the same as prices in the U.S.A.?

DR. KNABE: I want to summarize these questions and to answer as follows.

a) *Thickness of overburden and coal*

The geological conditions in the German mining districts are not uniform.

I only want to mention the relation between overburden and coal (Raack, 1962b).

| | Thickness of overburden: coal | Thickness of coal vein |
|-----------------------|----------------------------------|---------------------------|
| Rhineland | 2 : 1 | about 50m = 164 ft |
| (old mined out areas) | 0.3-0.5 : 1 | about 50m = 164 ft |
| (expected for future) | 2.5-3.0 : 1 | about 50m = 164 ft |
| Hessen | 6.5 : 1 | 5 to 10m = 16 to 33 ft |
| Halle/Leipzig area | 2.5-3.0 : 1 | |
| Lausitz | 3 - 5 : 1 | about 12m = 40 ft |

Some other figures by courtesy of *Rheinischer Braunkohlen-Bergbauverein* show the rapid increase of overburden disposal in the Rhineland, in order to keep the coal production on about the same level.

| | Relation of disposed overburden: mined coal | | | Coal production (million tons) |
|------|--|---|---|-----------------------------------|
| | m ³ | : | t | |
| 1956 | 0.83 | : | 1 | 82.1 |
| 1957 | 1.08 | : | 1 | 83.4 |
| 1958 | 1.41 | : | 1 | 80.1 |
| 1959 | 1.94 | : | 1 | 79.8 |

Within 4 years the ratio of overburden to coal has more than doubled, whereas the coal production has decreased slightly.

By courtesy of Dr. Gaertner (1962) I can also present some figures on the final depth of existing or planned mines.

| | Maximum height of overburden | Maximum depth of open pit |
|------------------------------------|---------------------------------|------------------------------|
| Opencast mine "Fortuna" (Garsdorf) | | |
| summer 1962 | 270 ft | 400 ft |
| planned final depth | 750 ft | 966 ft |
| Opencast mine "Frechen" | | |
| planned final depth | 633 ft | 833 ft |
| Planned opencast mine "Hambach" | | |
| planned final depth | 1,167 ft | 1,400 ft |

*Answers to questions presented at the symposium were prepared for the *Journal* after Dr. Knabe returned to Germany.

b) *The minimum thickness of brown-coal layer that can be mined economically*

This depends upon the overburden: coal ratio and the cost of the land. In the Rhineland no brown-coal layers less than 33 ft have been mined. For collecting data about minable coal reserves in Mideastern Germany, only coal layers of more than 6 ft have been considered.

c) *Price of coal in Germany and Ohio*

The price of raw brown coal in the Rhineland for public use amounts to DM 8.75 or \$2.19 per ton of coal F.O.B. railway loading point.

Screened raw brown coal costs DM 10.25 or \$2.55 per ton. There is an additional charge for truck loading of DM 0.50 or 12.5 cents a ton. This coal has a moisture content of about 60 per cent and a heating energy of 1,900 Kcal per kg (Hundhausen, 1935).

The dried and pressed brown-coal briquets with a moisture content of 14 per cent and a heating energy of about 4,900 Kcal per kg coal are sold at a price of DM 38, or \$9.5 per ton. Mass consumers get lower prices.

The moisture content of bituminous coal varies between 4 and 17 per cent (Trumbull, 1960). The price of strip-mined bituminous coal in Ohio was \$3.64 per short ton (sh tn) or \$4.03 per metric ton (T) in 1960 (Young, Anderson, and Hall, 1960).

The price per ton of strip-mined coal is higher, the price per unit of heating energy being cheaper in Ohio than in Germany. You can see this by a comparison with German bituminous coal too, which is mined only in very deep shaft mines. One metric ton of this coal had a price of DM 53 in 1960 (*Statistik der Kohlenwirtschaft*, 1960). At the present rate of exchange that would be \$13.25. The high level of German coal prices allows American coal exports to Germany. The freight rates do not exceed the price difference in the coastal area.

d) *Comparison of American and German mining methods*

Geological and economic conditions are different in the two countries. So we have to find successful ways of mining and reclamation at costs which may be different. Scanning foreign experiences for their usability in one's own country can thus be of help.

GLENN HOFFMAN: Are there any recommendations or laws governing the side slopes of spoil banks?

If so, what are they and on what principle do they depend?

DR. KNABE: I want to restrict my answer to Western Germany. The general mining law does not make special prescriptions, but it calls for an operating plan. In this plan, the side slope of spoil banks is fixed and is subject to approval by the Bureau of Mines.

In practice the plans differentiate between "living slopes" and "dead slopes." Each consists of several benches and slopes in the deep surface mines. "Living slopes" are those where there is a continuous change caused by the progress of the mining; safety strips must be provided to prevent slides caused by the heavy equipment on the benches and interruption of the whole operation by sudden repairs of an excavator or spreader. Hence, a general slope of 1:6 is prescribed. The single slope still has a ratio of 1:1.5. "Dead slopes," where there is no movement during longer periods and no heavy machinery on the benches, are allowed to have a general slope of 1:3. The Bureau of Mines is showing a trend to ask for an angle of repose of the single slopes of 1:3; in this case the mining company is permitted to make small benches only.

Around the open pits, mining leaves a general slope of 1:3, but it is intended to fill the pit to 1:6.

All these figures are preliminary. They have to be tested by experience at the first surface mine which works with overburden of 500, 700, or 1,000 ft.

The slope will always depend on the kind of overburden; rocky material stands better than gravel and sand, and much better than loam or clay. It depends also on the amount of wetting. Dry banks will stand better than water-logged ones. The results of time and vegetative cover of old spoil banks on slips have been reported by Barthel (1958).

Other recommendations exist with respect to the Ruhr Basin. This bituminous coal district with its overburden of shale and sandstone resembles Ohio more than the brown-coal area of the Rhineland. The recommendations suggest slopes of 1:2 up to a height of 33 ft. In higher spoil placers, small benches are to be left every 27 ft. (*Siedlungsverband Ruhrkohlenbezirk*, 1954).

H. GRANVILLE SMITH, *Columbus, Ohio*: How does the general climate in Germany and Ohio compare in regard to the success of such tree species as larch and white birch? Might these trees succeed in Ohio?

DR. KNABE: The general climate of Ohio is not too different from that of Germany. You have colder winters but warmer summers than we have. The rainfall in Ohio is higher than in the German flat land, but less than in the many mountains where there are no coal deposits.

I will mention four stations (Schenck, 1939).

| | Ohio | | Germany | |
|------------------------------|---------|-----------|----------------------|----------------------|
| | Wooster | Cambridge | Koeln (Rhineland) | Cottbus (Lausitz) |
| elevation, m above sea level | 314 | 247 | 56 | 75 |
| Average temperature year C | 9.7 | 10.7 | 10.0 | 8.8 |
| January C | -3.0 | -1.4 | 1.9 | -1.0 |
| July C | 22.0 | 22.6 | 18.2 | 18.6 |
| rainfall | | | | |
| total year mm | 988 | 1,000 | 678 | 620 |

July is the month with the highest rainfall in all four stations. The climate is not identical, but is similar, hence experiments with German trees such as white birch and European larch might be successful.

Experiments with different seed sources would be needed. The seed source "Alpenlärche" cannot be recommended. German tree species with higher temperature requirements might grow better in Ohio.